Environmental Assessment in the UH-1Y and AH-1Z

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ABSTRACT

The United States Marine Corps USMC Upgrade Program involves the remanufacture of all light/attack helicopters in the fleet to extend their service-life into the year 2020. In order to assess whether air quality was favorable for aircrew in the UH-1Y and AH-1Z aircraft, levels of carbon monoxide and hydrocarbons were measured during ground and flight operations. In the past, cockpit gas detection during flight was prohibitive, due to detector size and the resulting inability to mount sensors on aircrew. In this report, a novel method for measurement of combustion gases during ground and flight operations is discussed. Commercially-available man-mounted sensors provide crucial cockpit air quality data in an unobtrusive manner, while eliminating the need for mounting equipment inside the aircraft, possible alteration of airframe, and reducing the risk of interference and injury to aircrew. Cockpit air-quality findings are discussed and recommendations are made to mitigate risk to aircrew.

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BACKGROUND

A top priority of the United States Marine Corps (USMC) is the H-1 Upgrade Program. This program involved the remanufacture of all light/attack helicopters in the fleet to extend their service-life into the year 2020. The Marine Corps has modernized its Bell-model helicopters, giving them new designations: UH-1Y and AH-1Z. Both aircraft are currently in low-rate initial production (LRIP). By 2014, the Marine Corps will have procured 100 UH-1Y Hueys and 180 AH-1Z Super Cobras (Ref. 1).

Major upgrades addressed dynamics, weapon sub-systems, integrated avionics and the cockpit. New four-bladed rotor systems are coupled to an increased-power drive train. Aircraft utilities are enhanced with a new auxiliary power unit (APU) and improved hydraulic and electrical systems. The weapons and avionics systems are fully integrated into an advanced cockpit (Ref 2).

These improvements have increased the range, speed, payload, and lethality of these aircraft while decreasing their logistic footprint. They also introduced many other characteristics that required evaluation from a human factors perspective. Among these characteristics there was the potential for alteration of air quality, due to cockpit improvements and the increased armament capability of the Huey and Super Cobra.

During the developmental and operational test phase of the H-1 Upgrades program (DT/OT), reports from aircrew of noxious cockpit odors during and after weapons firing suggested a need for assessment of cockpit air quality in these aircraft. These reports, combined with the multitude of changes implemented in the H-1 Upgrade program, led PMA-276 to task the Crew Performance Technology Branch with assessment of cockpit air quality.

PURPOSE

Prior to deploying UH-1Y and AH-1Z aircraft, it was essential to ensure that cockpit air quality was not degraded by an increase in carbon monoxide, in accordance with MIL-STD-1472 (Ref. 3) and further, that the cockpit was free of other potentially toxic levels of combustion by-products (such as hydrocarbons).

The novel method of environmental assessment described here employs man-mounted, commercially-available monitors to provide in-flight cockpit environmental data in an unobtrusive manner. The data-collection devices used in this study were inexpensive, easy to maintain, and small in size. These factors, in addition to ease of use, should promote future assessment in other aircraft platforms in order to prevent performance decrements, loss of situational awareness, and serious mishaps.

Testing was conducted to determine levels of carbon monoxide and hydrocarbons in the cockpit of the UH-1Y and AH-1Z during ground and flight operations. Multiple flights were evaluated over the course of fifteen months. Results were evaluated with regard to altitude, weapons-release, and other factors. The obtained air-quality data was then compared to limits specified in MIL-STD 1472F and various regulatory agencies' established exposure limits.

METHODS

Testing was conducted at NAS Patuxent River, MD and at Yuma Proving Ground (YPG), AZ on both pre-production and production-representative AH-1Z and UH-1Y aircraft. Tests were conducted concomitant with weapons-delivery missions.

Commercially-available gas monitors (GasAlert Micro, purchased from BW Technologies) were installed on AIRSAVE survival vests to obtain cockpit and peri-aircraft levels of oxygen, carbon monoxide, and hydrocarbons. These battery-powered monitors permitted over 15 hours of continuous data collection with real-time display via an LCD screen. Each device weighed only 7.3 ounces (211 g) and measured 2.4 x 4.0 x 1.3 in / 6 x 10 x 3.3 cm in size, eliminating concern with weight issues or of interference with other gear.

Gas analyzers were placed in pockets (Fig. 1) specifically designed to integrate with aircrews' CMU-33/P flight vests and not to interfere with any existing survival equipment. Test personnel installed one monitor per aircrew vest before each test flight. Gas levels were measured during normal ground, preflight and flight operations (including level flight, hovering, dives, and chaff/flare release). Data was collected continuously, and monitors were retrieved post-flight for data download and analysis. At the conclusion of each test, crew members were briefly interviewed by a test-team physiologist and observed for clinical signs of carbon monoxide and/or hydrocarbon exposure.

Figure 1
Monitor installed in pocket

DATA ANALYSIS

At the conclusion of each test, monitors were removed from survival vest pockets. Data files were downloaded from each monitor's data storage card to a laptop computer. GasAlert Micro software was used to construct graphs from data spreadsheets. Conversion into graphs was performed automatically by the software package, and allowed truncations for displaying specific portions of the data.

Pre- and post-flight interview data and test personnel observations were collected, reviewed, and archived.

RESULTS AND DISCUSSION

Carbon monoxide is a colorless, odorless gas and a normally-occurring by-product of combustion. Hydrocarbons are also liberated in this process and carry a noxious odor.

The effect of carbon monoxide on human health is well-documented in the literature (Refs. 4, 5, 6.). Carbon monoxide binds to hemoglobin with over 200-fold greater affinity than oxygen, and causes hypoxia by displacing oxygen. This means that CO stays bound to hemoglobin molecules far longer, and prevents oxygen from getting into the body. Therefore, the resulting hypoxia actually outlasts the period of exposure.

Symptoms of carbon monoxide exposure vary according to level, duration, and miscellaneous individual factors (smoking status, general health, altitude, and others). Of particular interest to the military aviation community is the fact that populations at increased risk of carbon monoxide toxicity (above normal) include those at higher altitudes.

Early signs of toxicity include headache, fatigue, shortness of breath, tightening across the chest, nausea, and dizziness. With continued exposure/duration, these can escalate into more-serious complications such as vomiting, vision problems, unconsciousness and death. Even relatively mild clinical effects produce significant cognitive impairment (Ref. 4), thereby affecting situational awareness of aircrew. This in turn could negatively impact flight safety and mission effectiveness.

Initial diagnosis of CO toxicity is difficult because symptoms closely resemble those of influenza. Treatment ranges from getting fresh air at early stages to advanced life support and/or use of a hyperbaric chamber in more severe cases. (Ref. 5) Chronic exposure to CO can also produce irreversible neurological damage (Ref. 6).

In an effort to prevent exposure and reduce likelihood of short- and long-term effects of carbon monoxide exposure, regulatory agencies have established limits (Refs. 7, 8). In addition to the MIL-STD, these federal guidelines can be applied to protect personnel (Table 1).

	TLV [1]	PEL [2]	STEL [3]	IDLH [4]
Carbon Monoxide (CO)	25 ppm	50 ppm	-	1200 ppm

[1] *Threshold Limit Value*
[2] *Permissible Exposure Limit*
[3] *Short-Term Exposure Limit*
[4] *Immediately Dangerous to Life and Health*

Table 1
OSHA Guidelines

The EPA defines binary limits; the agency's National Ambient Air Quality Standard reflects the importance of both duration and concentration of exposure (Table 2). According to the standard, higher concentrations of ambient CO require stricter time limits.

	Primary Standard	Averaging Times
Carbon Monoxide (CO)	9 ppm (10 mg/m^3)	8-hour
	35 ppm (40 mg/m^3)	1-hour

Table 2
EPA Standards

Due to the potential effects of CO toxicity, it is critical that levels be assessed during developmental and operational testing. This type of risk-mitigation could prevent major mishaps and protect aircrew health. Further, detection and correction of sub-clinical CO exposure may enhance crew performance.

In the first phase of cockpit air quality testing, carbon monoxide levels were low, with relatively small peaks (4 – 8 ppm CO) occurring during and after weapons, flare, or chaff release, and lasting four to twenty seconds. No hydrocarbons were detected in the cockpit during any phase of testing.

Carbon monoxide was not detected during ground operations, normal flight, hovering, or other transitive maneuvers which did not involve weapons release.

Pilots and aircrew instrumented with portable gas analyzers reported cockpit odor during and after weapons release. However, they indicated no physical symptoms of toxic exposure, nor were any clinical signs observed post-flight by test personnel.

Data collected in subsequent test episodes revealed much higher levels of CO during and after extended gun volleys in the AH-1Z, as shown in Figs. 2 and 3.

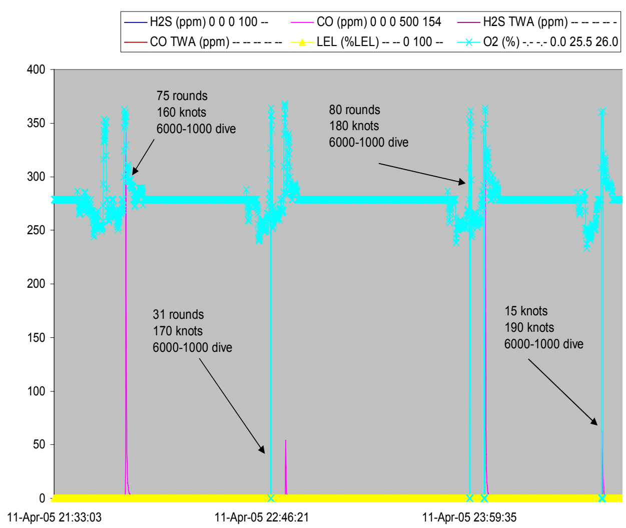

Figure 2
AH-1Z 11 April 05 Flight Test Data

These tests, performed during April 2005, showed CO levels in excess of 500 ppm in some cases. These relatively higher CO peaks were transient, and occurred – as before - only during and after weapons release. Aircrew did not exhibit any signs of toxicity consistent with overexposure to CO or hydrocarbons.

According to FAA standards, these levels are unacceptable; due to the short duration of exposure and normal (approx. 20%) levels of cockpit oxygen, the recorded levels of carbon monoxide did not represent a toxic exposure.

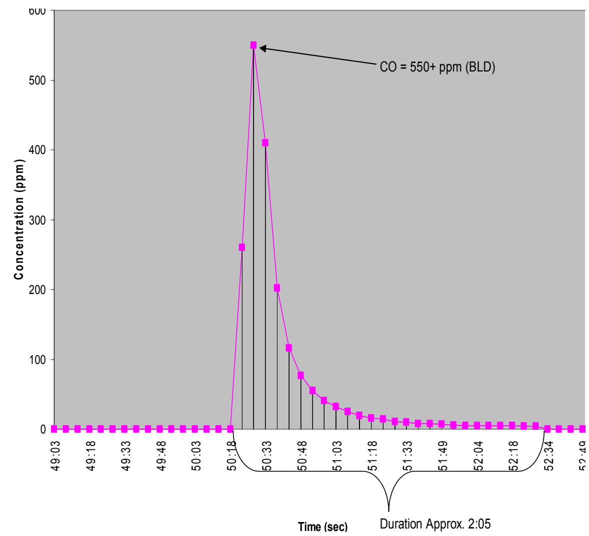

Figure 3
AH-1Z 12 April 05 Flight Test Data

Nonetheless, these instances of elevated cockpit CO indicated a need for further testing, particularly at higher altitudes, when atmospheric oxygen is reduced and aircrew are at increased risk of carbon monoxide toxicity. The potential for increased CO during longer or repetitive gun volleys was also of concern.

It was later reported that the AH-1Z test aircraft had been modified to accommodate other test equipment. Since it was unclear whether these instrumentation holes contributed to increased CO levels, follow-on testing was performed with a production-representative AH-1Z aircraft.

The same method was employed as described previously. During flight tests, guns were fired in approximately 100-round bursts. Each volley lasted approximately 10 seconds and was spaced about twenty seconds apart in order to evaluate the potential for gas accumulation.

Results from the production-representative Super Cobra showed no carbon monoxide during or after extended (10-sec) and repeated gun volleys, or at any other portion of the flight. Test data also showed that hydrocarbons were not present in cockpit air.

These data confirmed that high CO levels were related to the test-instrumentation holes. Regardless of this conclusion, testing effectively excluded the risk of carbon monoxide or hydrocarbon toxicity to aircrew in intact Super Cobra and Huey cockpits. It is also clear from this study that high-CO levels *can* occur in cockpits whose seals are worn or damaged, or other cabin breaches (e.g., combat damage).

These tests also demonstrate a new mode of in-flight environmental assessment. The GasAlert Micro can be equipped with various sensors to permit unobtrusive and real-time evaluation of multiple airborne contaminants. Because the monitor is both light-weight and small, it can be man-mounted without gear interference.

CONCLUSIONS

Based on the data collected, carbon monoxide is not a cause for concern in *intact* UH-1Y and AH-1Z aircraft. However, results obtained from tests in the compromised AH-1Z cockpit indicate that aircrew could be at risk in certain situations (worn door/window seals or combat damage to the aircraft). These data argue a need for enhanced awareness by aircrew, a revision of training protocol, and further assessment in theatre-representative scenarios.

This novel approach to multiple gas assessment provides a model for future testing of other gas species in various aircraft.

RECOMMENDATIONS

1. Training for aircrew to increase awareness of the symptoms of CO exposure and encourage development of reasonable strategies to mitigate risk in situations where the cockpit may become compromised.

2. Modification of the MIL-STD to state CO levels as parts-per-million (ppm) in air, instead blood levels of carboxyhemoglobin. The guidelines in use require a blood draw (impossible during flight), and apply after toxic exposure has occurred. Further, conversion of parts-per-million to projected blood levels is unreliable. Restating limits in ppm units will permit proactive assessment and prevent or reduce exposure, in accordance with the spirit of the MIL-STD.

3. Conduct broader surveys to determine:

- CO levels in various aircraft, and under conditions which best approximate current operational and theatre conditions (including worst-case).
- Effects of altitude, airspeed, direction, rotorwash, weapons release, and cockpit intrusion on cabin carbon monoxide levels.

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